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(54) **COOLING SYSTEM AND CONTROL METHOD OF COOLING SYSTEM**

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USPC **700/275**; 318/268; 700/280; 62/241; 62/296; 62/259.2; 62/186; 62/408; 180/68.1; 165/121

(58) **Field of Classification Search**
USPC 700/275, 280; 318/268; 180/68.1; 165/121; 62/241, 296, 259.2, 186, 408
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,490,572 A 2/1996 Tajiri et al.
5,937,664 A * 8/1999 Matsuno et al. 62/259.2

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1 504 949 A1 2/2005
EP 1 983 603 A1 10/2008

(Continued)

OTHER PUBLICATIONS

Mar. 29, 2012 Office Action issued in U.S. Appl. No. 12/295,212.

(Continued)

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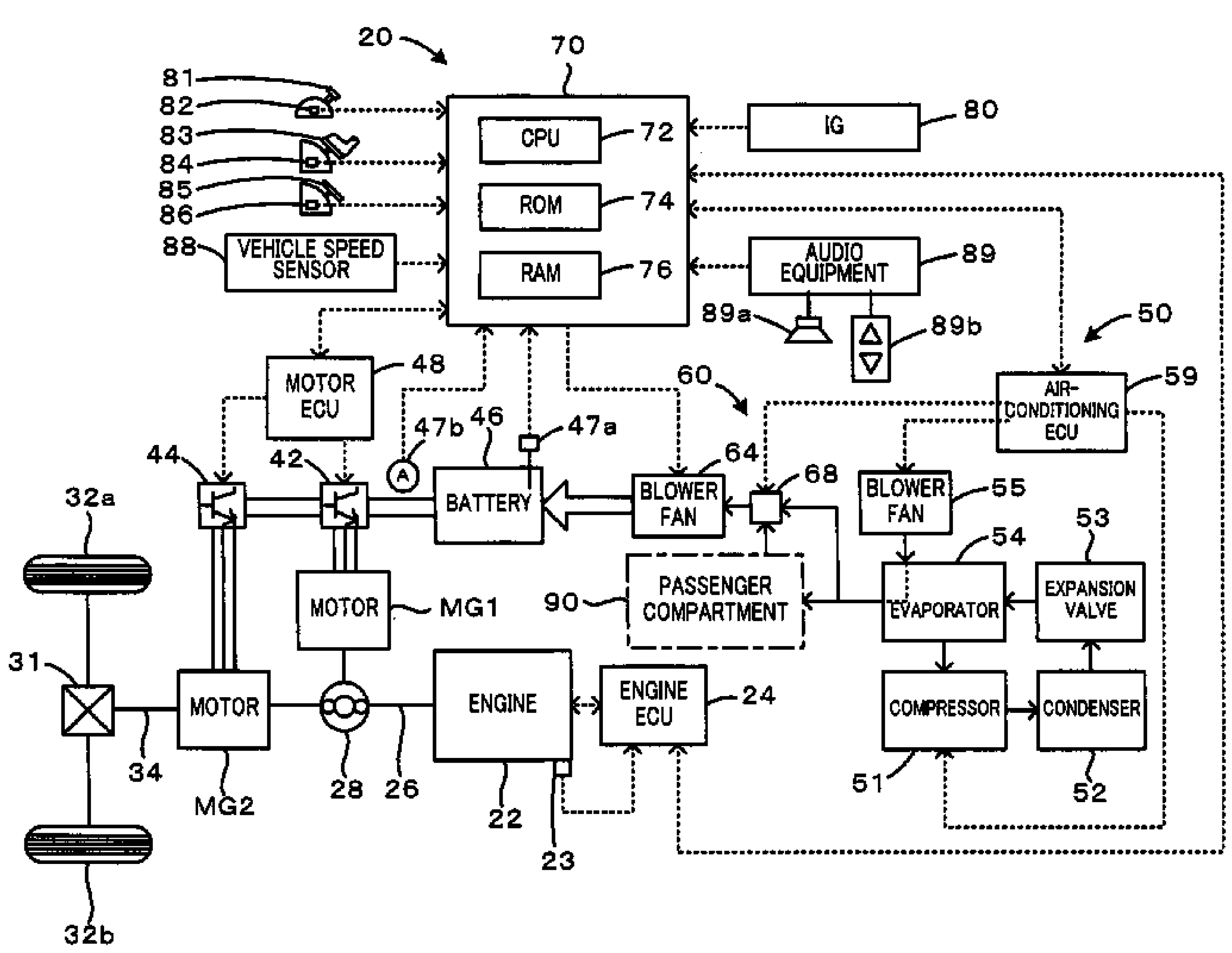
(57) **ABSTRACT**

A cooling system constructed to cool down an accumulator mounted on a motor vehicle is herein presented. The cooling system sequentially controls an air blower to restrict the air blow to the accumulator, controls the air blow mode switchover module to switch over the active air blow mode after restriction of the air blow to the accumulator, and controls the air blower to release the restriction of the air blow to the accumulator after the switchover of the active air blow mode by the air blow mode switchover module.

8 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,675,597	B2	1/2004	Ieda et al.	
6,691,523	B1	2/2004	Sangwan et al.	
7,024,871	B2	4/2006	Zhu et al.	
7,152,417	B2	12/2006	Morishita et al.	
7,348,741	B2	3/2008	Minekawa et al.	
7,360,370	B2	4/2008	Shah et al.	
7,767,354	B2	8/2010	Saito et al.	
2002/0140389	A1	10/2002	Ohki et al.	
2003/0080714	A1	5/2003	Inoue et al.	
2003/0118891	A1	6/2003	Saito et al.	
2003/0209022	A1	11/2003	Ieda et al.	
2003/0233839	A1	12/2003	Hirose et al.	
2005/0056472	A1	3/2005	Smith et al.	
2005/0168180	A1 *	8/2005	Minekawa et al.	318/268
2006/0080986	A1	4/2006	Inoue	
2006/0186213	A1	8/2006	Carey et al.	
2007/0027580	A1	2/2007	Ligtenberg et al.	
2007/0033953	A1	2/2007	Gao	
2007/0089442	A1	4/2007	Tsuchiya	
2007/0144190	A1	6/2007	Temmyo et al.	
2007/0178346	A1	8/2007	Kiya et al.	
2009/0024252	A1	1/2009	Aridome et al.	
2009/0133859	A1	5/2009	Suzuki et al.	
2009/0248204	A1	10/2009	Kikuchi et al.	
2010/0241308	A1	9/2010	Kikuchi et al.	

FOREIGN PATENT DOCUMENTS

JP	A-7-223428	8/1995
JP	A-09-086137	3/1997
JP	A-2001-291532	10/2001
JP	A-2002-211226	7/2002
JP	A-2003-279180	10/2003
JP	A-2004-001674	1/2004
JP	2004194384 A *	7/2004
JP	A-2004-194384	7/2004
JP	A-2004-255960	9/2004
JP	A-2005-93434	4/2005
JP	A-2005-178406	7/2005
JP	A-2005-254974	9/2005
JP	A-2005-306197	11/2005
JP	A-2005-343377	12/2005
JP	A-2006-111203	4/2006
JP	A-2006-143183	6/2006
WO	WO 2005/092650 A1	10/2005

OTHER PUBLICATIONS

Nov. 26, 2012 Office Action issued in U.S. Appl. No. 12/295,212.

May 19, 2011 Office Action issued in U.S. Appl. No. 12/294,487.

Sep. 27, 2011 Office Action issued in U.S. Appl. No. 12/294,487.

Jan. 11, 2012 Advisory Action issued in U.S. Appl. No. 12/294,487.

Feb. 15, 2012 Office Action issued in U.S. Appl. No. 12/294,487.

May 23, 2012 Notice of Allowance issued in U.S. Appl. No. 12/294,487.

U.S. Appl. No. 12/295,212 in the name of Suzuki filed on Sep. 29, 2008.

U.S. Appl. No. 12/294,487 in the name of Kikuchi filed on Sep. 25, 2008.

* cited by examiner

FIG. 1

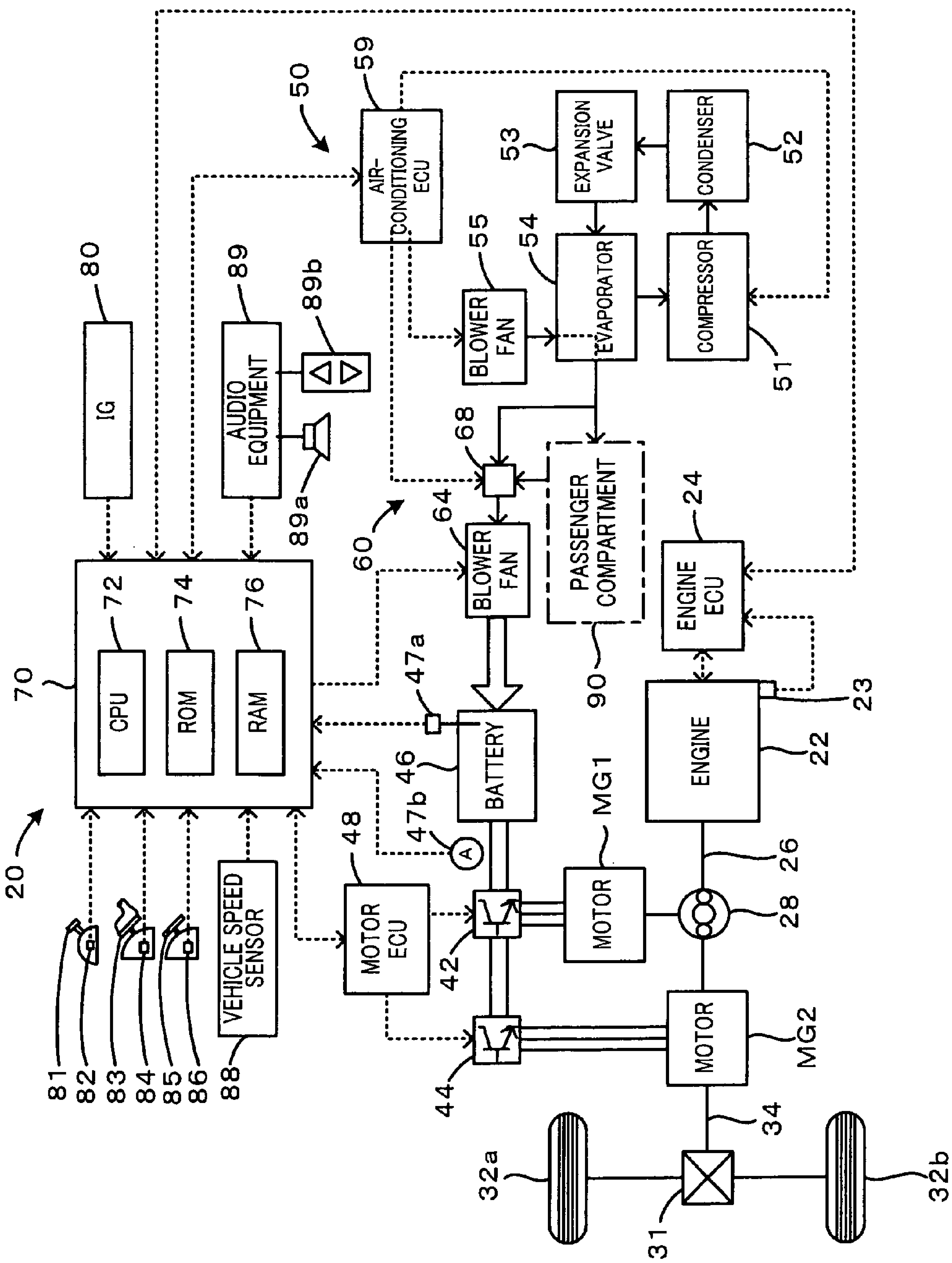

20
70
CPU
72
ROM
74
RAM
76
80
IG
89
AUDIO EQUIPMENT
89a
89b
50
59
AIR-CONDITIONING ECU
53
EXPANSION VALVE
52
CONDENSER
54
EVAPORATOR
51
COMPRESSOR
55
BLOWER FAN
60
64
BLOWER FAN
68
90
PASSENGER COMPARTMENT
24
ENGINE ECU
23
22
ENGINE
26
28
47a
47b
46
BATTERY
48
MOTOR ECU
MG1
MOTOR
MG2
MOTOR
42
44
34
31
32a
32b
VEHICLE SPEED SENSOR
81
82
83
84
85
86
88

FIG. 2

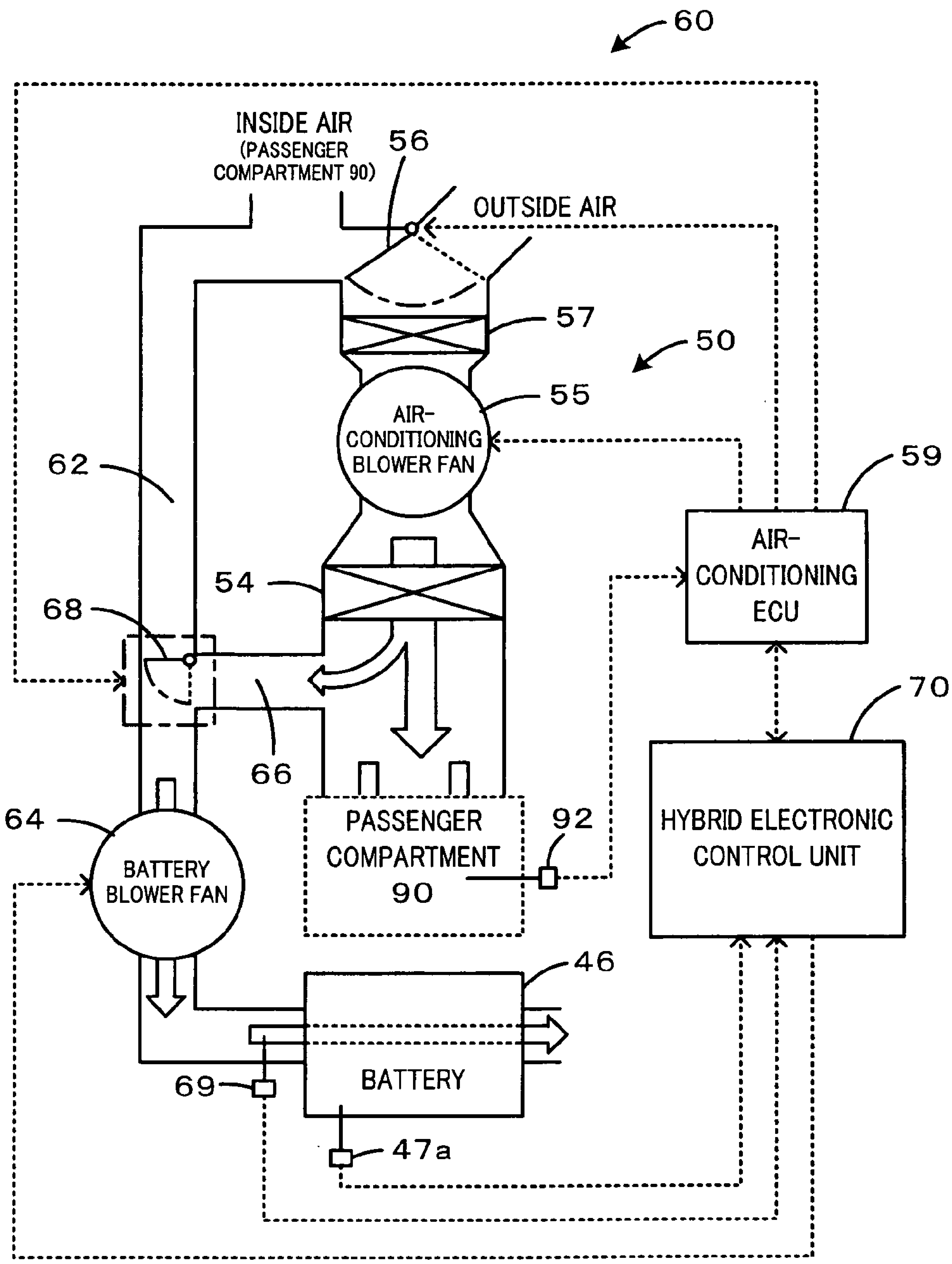

60
INSIDE AIR
(PASSENGER COMPARTMENT 90)
56
OUTSIDE AIR
57
50
55
AIR-CONDITIONING BLOWER FAN
62
59
AIR-CONDITIONING ECU
54
68
70
66
64
PASSENGER COMPARTMENT 90
92
HYBRID ELECTRONIC CONTROL UNIT
BATTERY BLOWER FAN
46
BATTERY
69
47a

FIG. 3

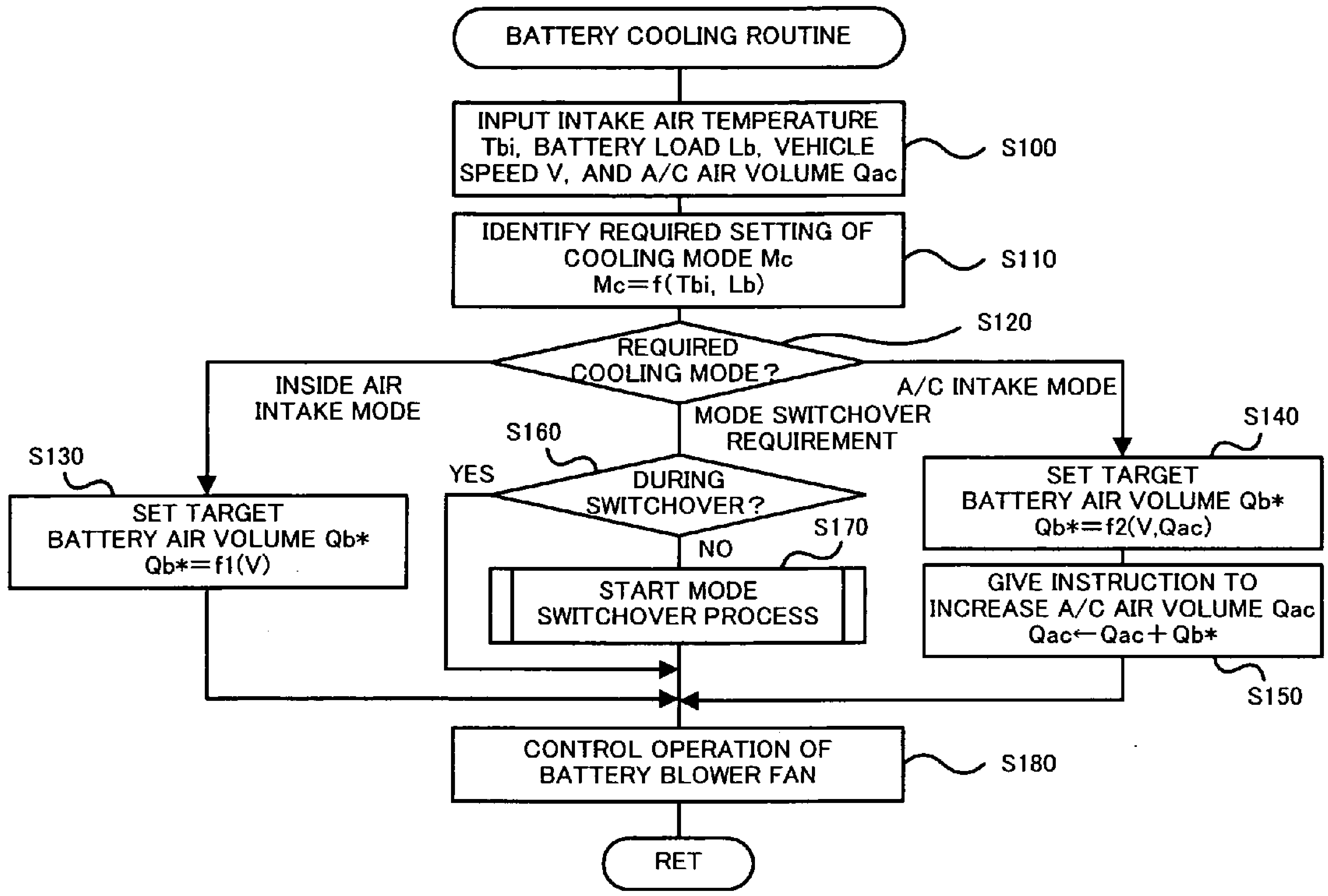

BATTERY COOLING ROUTINE
INPUT INTAKE AIR TEMPERATURE Tbi, BATTERY LOAD Lb, VEHICLE SPEED V, AND A/C AIR VOLUME Qac
S100
IDENTIFY REQUIRED SETTING OF COOLING MODE Mc
Mc=f(Tbi, Lb)
S110
REQUIRED COOLING MODE?
S120
INSIDE AIR INTAKE MODE
A/C INTAKE MODE
MODE SWITCHOVER REQUIREMENT
S130
SET TARGET BATTERY AIR VOLUME Qb*
Qb*=f1(V)
S160
DURING SWITCHOVER?
YES
NO
S170
START MODE SWITCHOVER PROCESS
S140
SET TARGET BATTERY AIR VOLUME Qb*
Qb*=f2(V,Qac)
GIVE INSTRUCTION TO INCREASE A/C AIR VOLUME Qac
Qac←Qac+Qb*
S150
CONTROL OPERATION OF BATTERY BLOWER FAN
S180
RET

FIG. 4

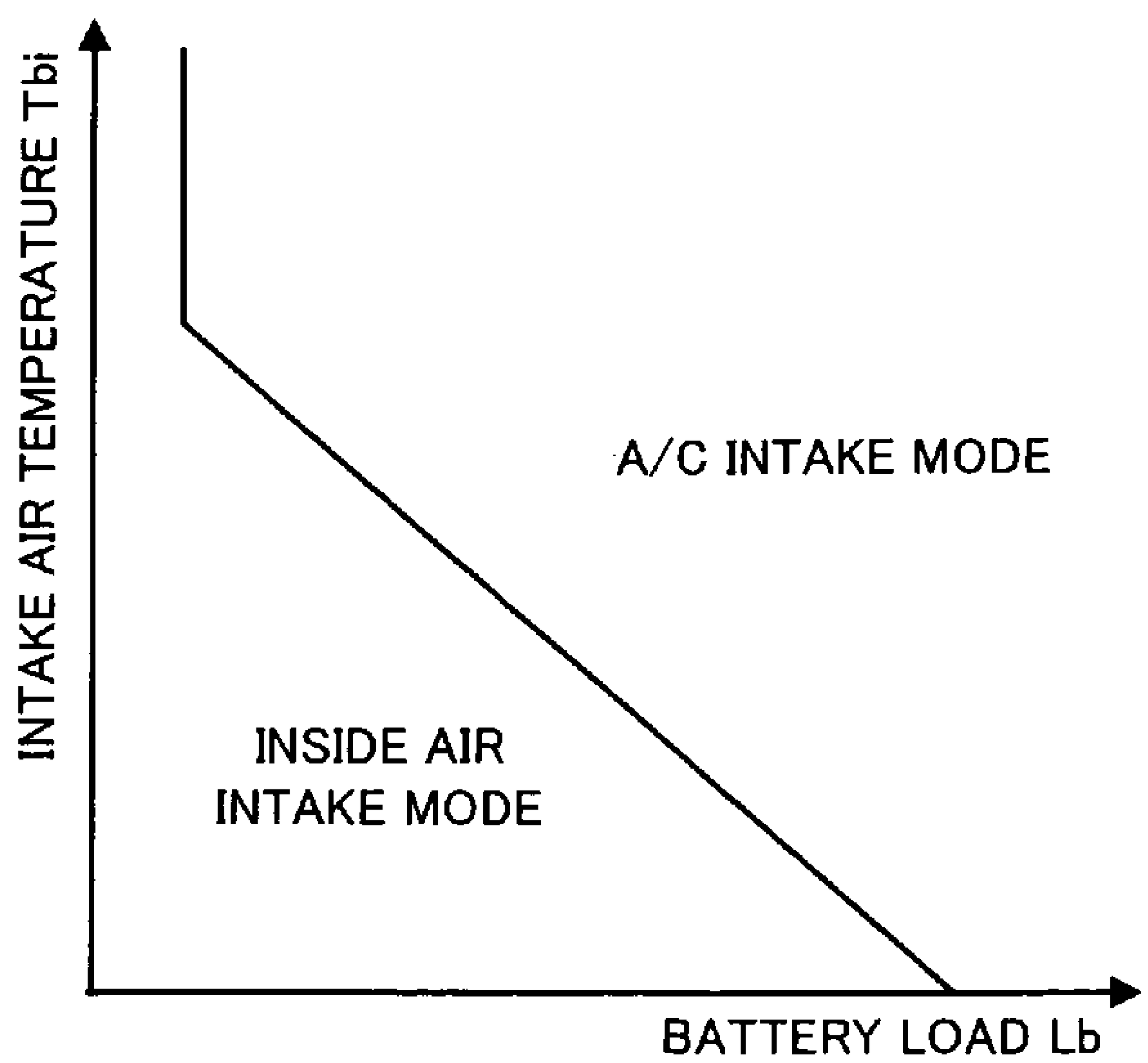

INTAKE AIR TEMPERATURE Tbi
A/C INTAKE MODE
INSIDE AIR INTAKE MODE
BATTERY LOAD Lb

FIG. 5

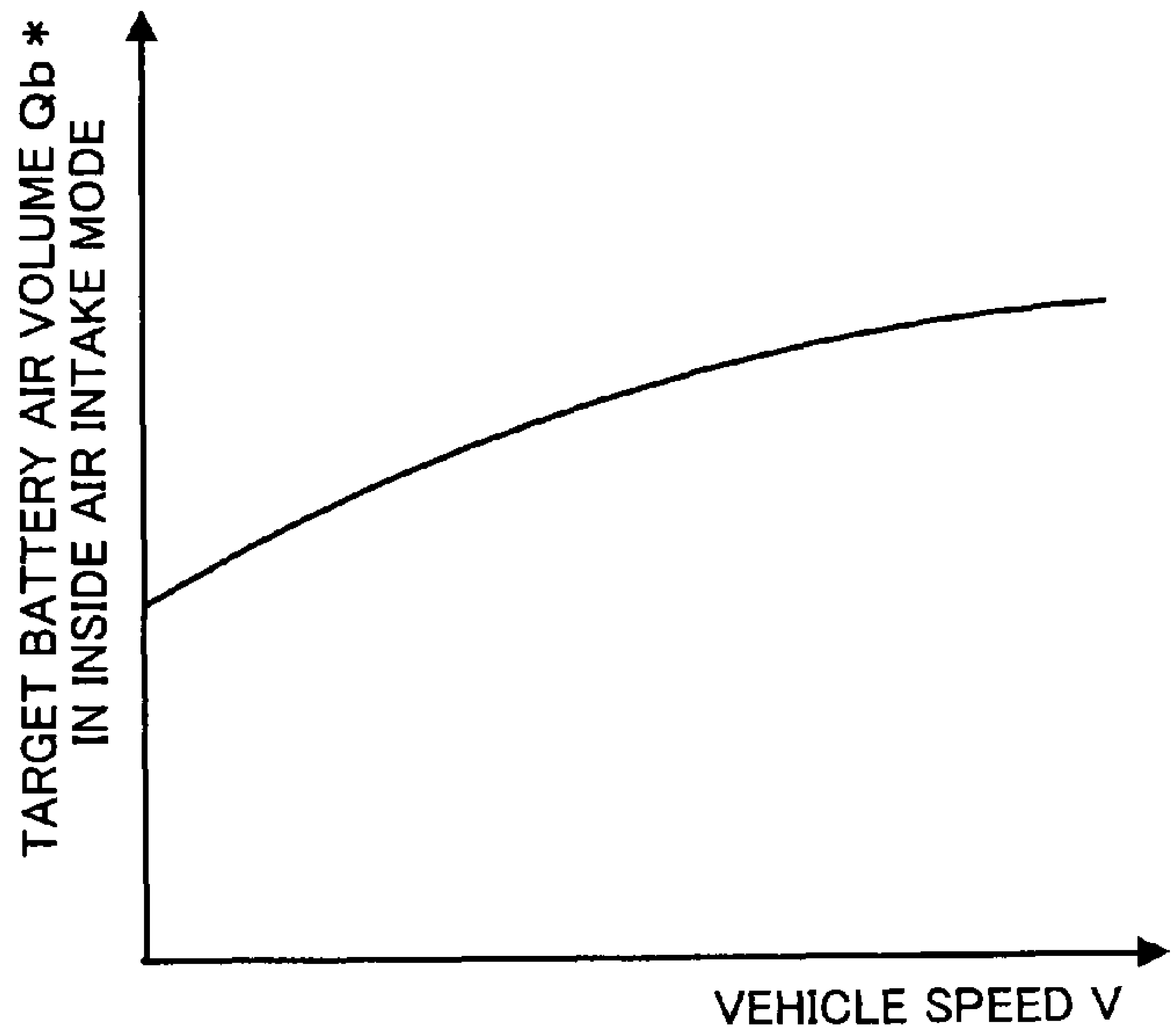

TARGET BATTERY AIR VOLUME Qb *
IN INSIDE AIR INTAKE MODE
VEHICLE SPEED V

FIG. 6

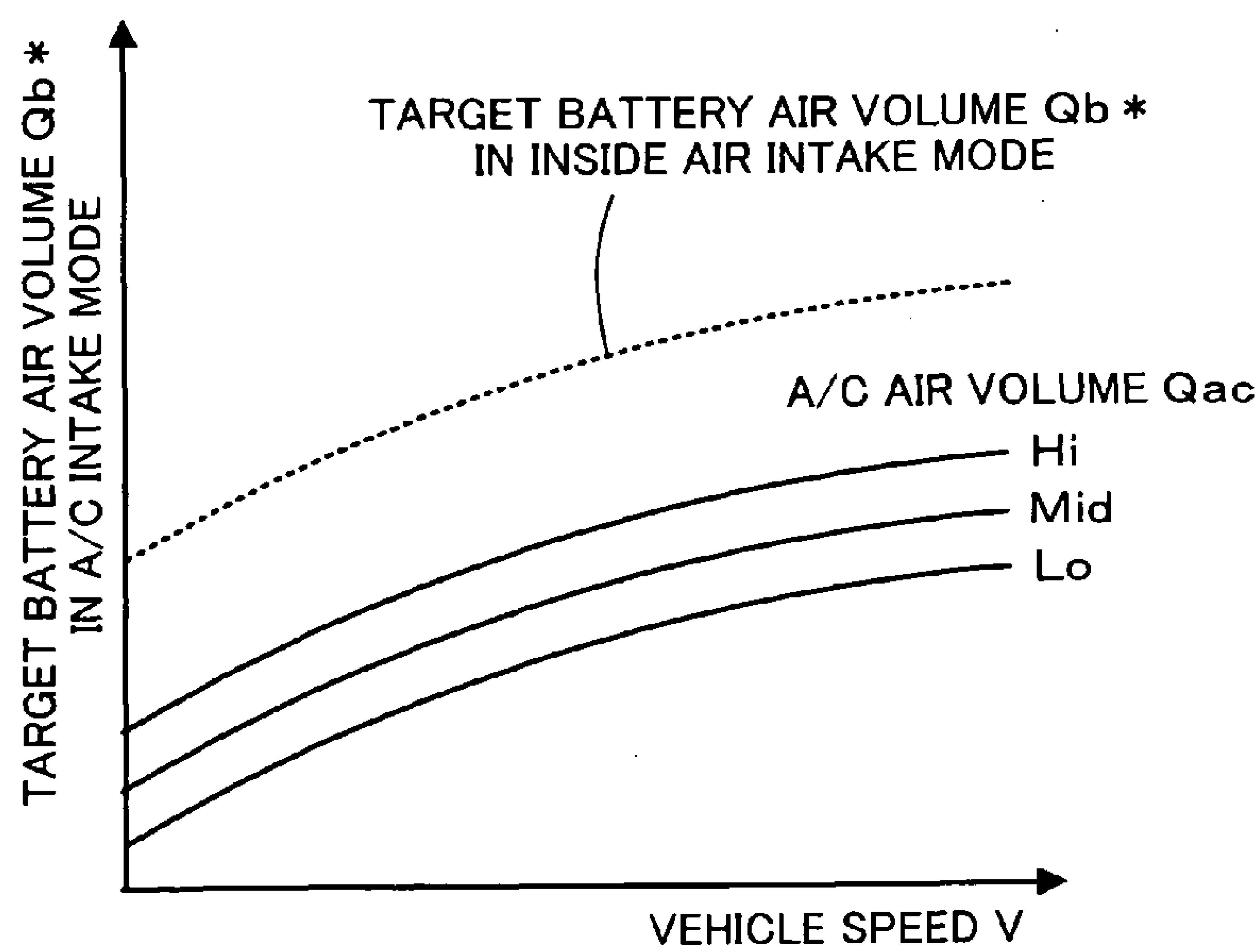

TARGET BATTERY AIR VOLUME Qb *
IN A/C INTAKE MODE
TARGET BATTERY AIR VOLUME Qb *
IN INSIDE AIR INTAKE MODE
A/C AIR VOLUME Qac
Hi
Mid
Lo
VEHICLE SPEED V

FIG. 7

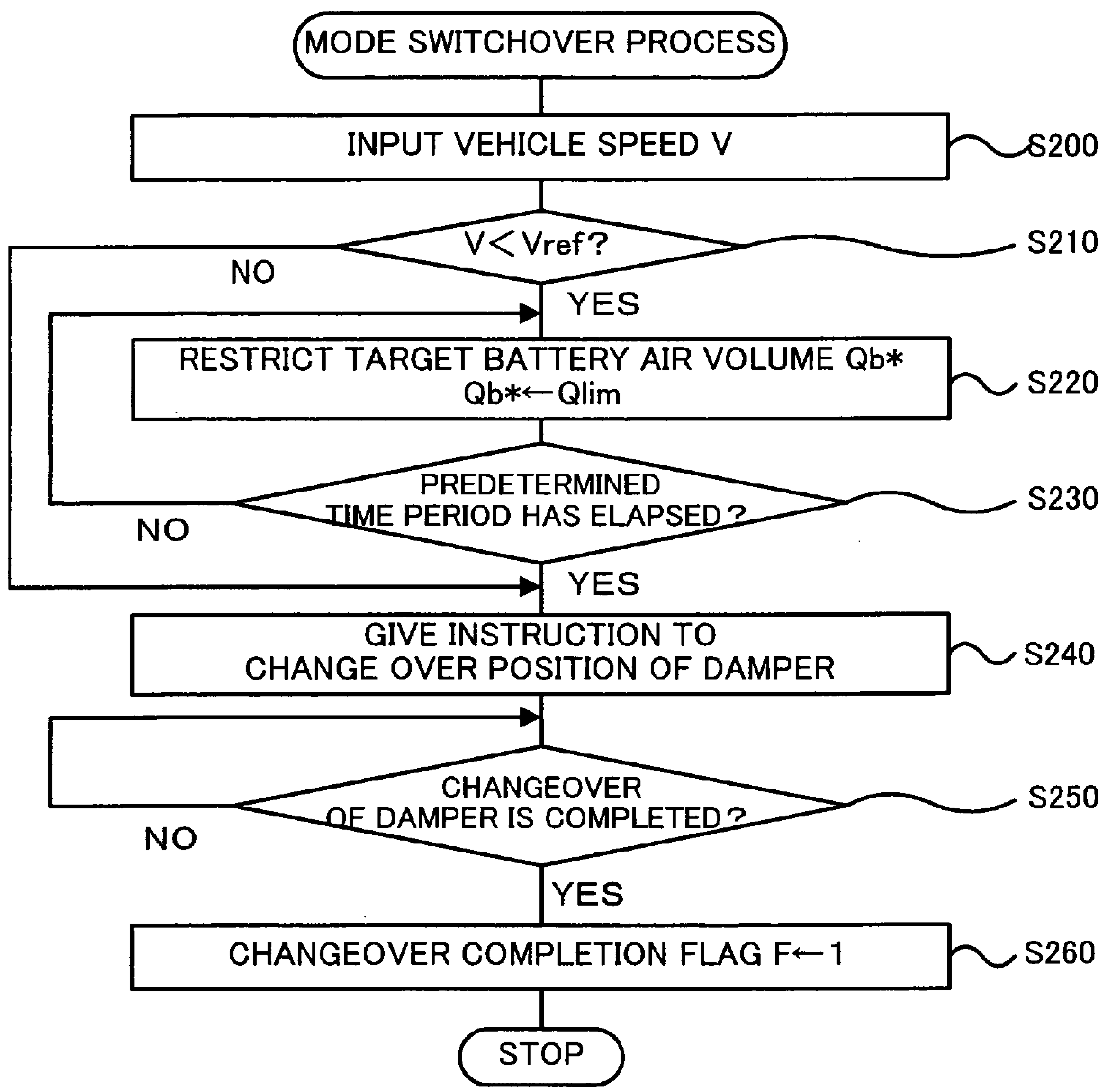

MODE SWITCHOVER PROCESS
INPUT VEHICLE SPEED V
S200
V<Vref?
S210
NO
YES
RESTRICT TARGET BATTERY AIR VOLUME Qb*
Qb*←Qlim
S220
PREDETERMINED
TIME PERIOD HAS ELAPSED?
S230
NO
YES
GIVE INSTRUCTION TO
CHANGE OVER POSITION OF DAMPER
S240
CHANGEOVER
OF DAMPER IS COMPLETED?
S250
NO
YES
CHANGEOVER COMPLETION FLAG F←1
S260
STOP

FIG. 8

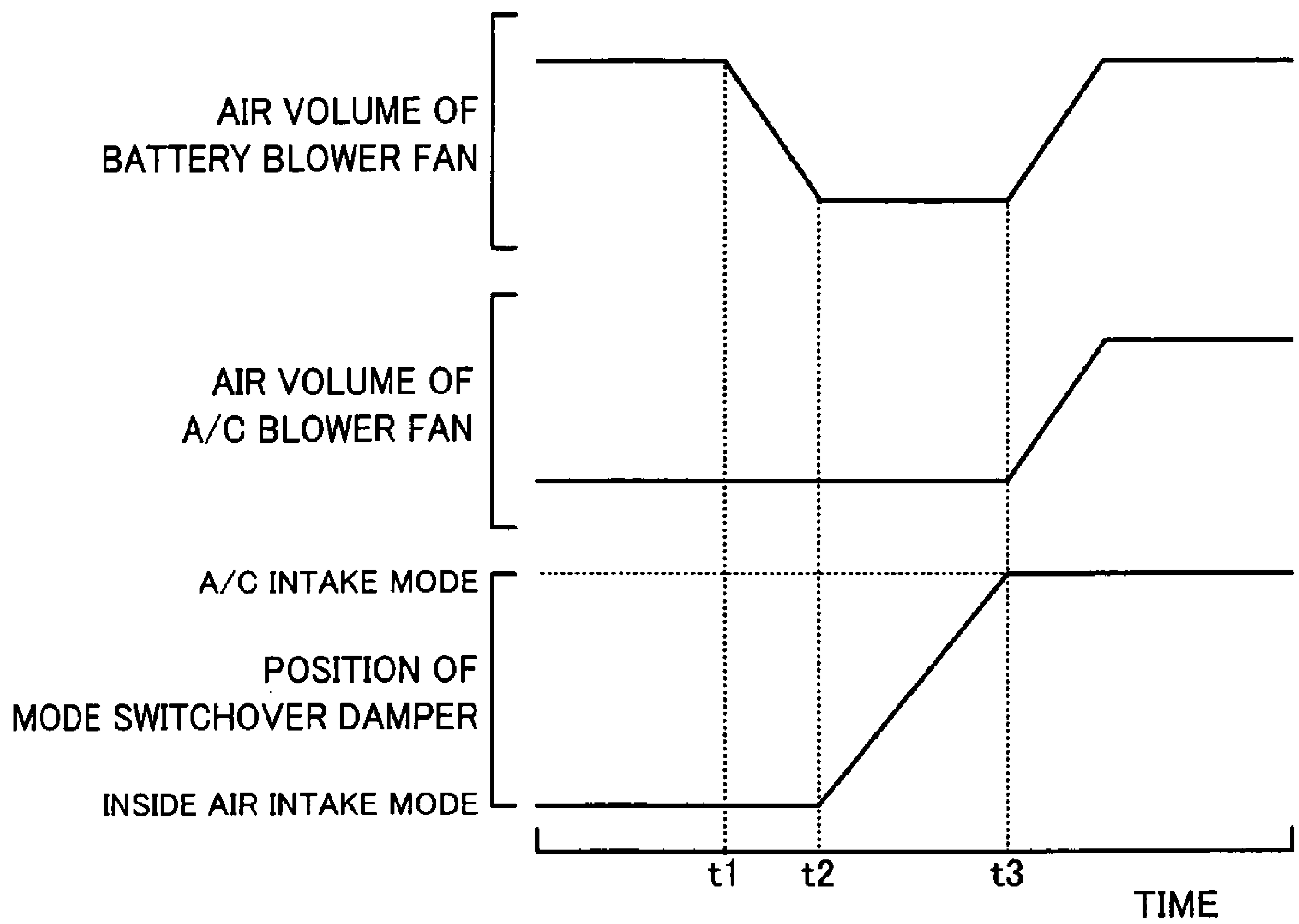
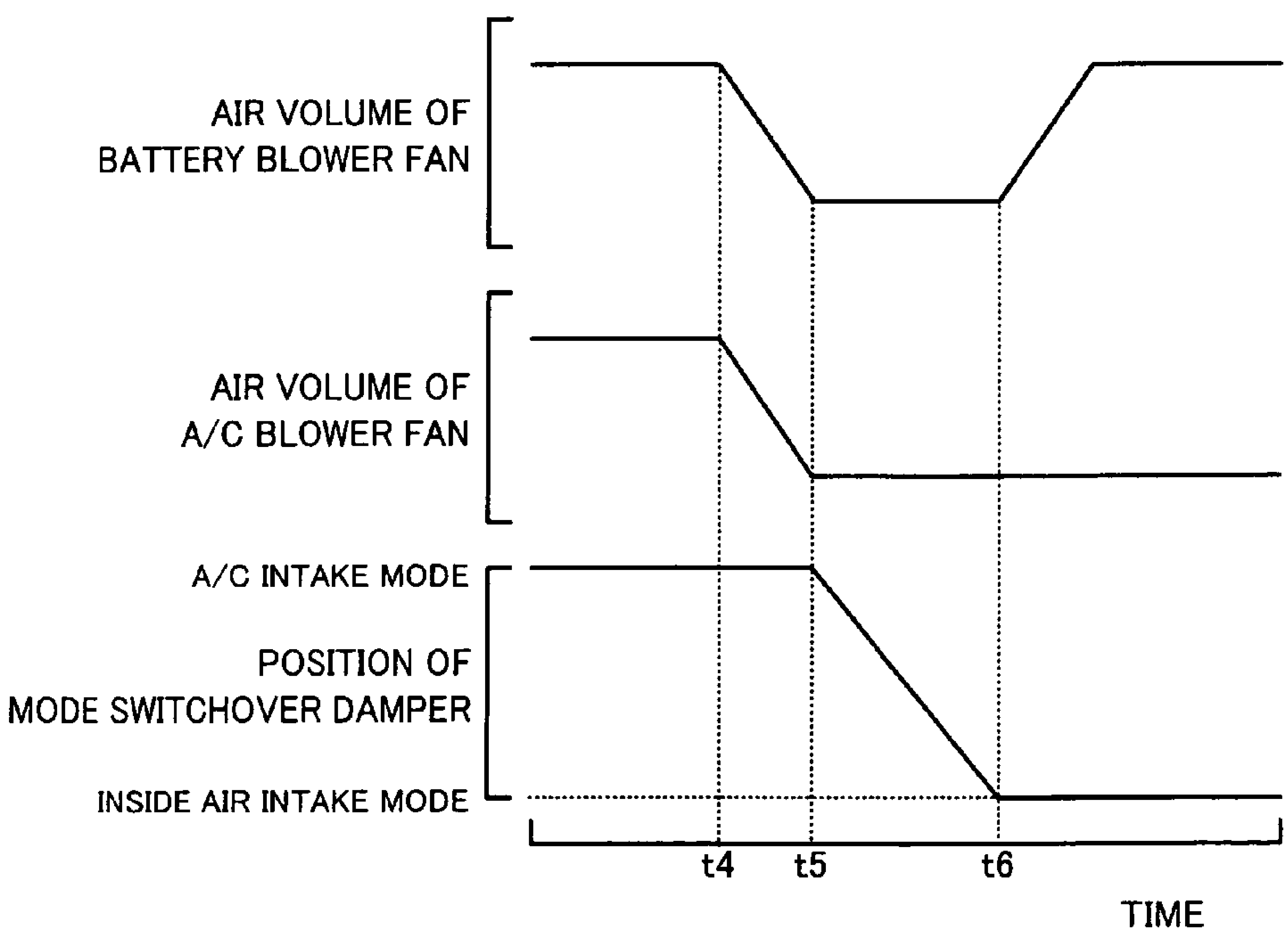

AIR VOLUME OF
BATTERY BLOWER FAN
AIR VOLUME OF
A/C BLOWER FAN
A/C INTAKE MODE
POSITION OF
MODE SWITCHOVER DAMPER
INSIDE AIR INTAKE MODE
t1
t2
t3
TIME

FIG. 9


AIR VOLUME OF
BATTERY BLOWER FAN
AIR VOLUME OF
A/C BLOWER FAN
A/C INTAKE MODE
POSITION OF
MODE SWITCHOVER DAMPER
INSIDE AIR INTAKE MODE
t4
t5
t6
TIME

COOLING SYSTEM AND CONTROL METHOD OF COOLING SYSTEM

TECHNICAL FIELD

The present invention relates to a cooling system configured to cool down an accumulator mounted on a motor vehicle, as well as to a control method of such a cooling system.

BACKGROUND ART

One proposed structure of a cooling system mounted on a motor vehicle changes over the position of a damper to change over the air blow pathway for cooling down the battery between an air flow path of taking in the air inside or outside of a passenger compartment of the motor vehicle and blowing the intake air to a battery and an air flow path of taking in the air cooled down by an evaporator and blowing the cooled intake air to the battery (see, for example, Patent Documents 1 and 2). This prior art cooling system changes over the position of the damper based on the temperature of the battery, in order to keep the battery operated in an adequate temperature range.

Patent Document 1: Japanese Patent Laid-Open No. 2005-93434

Patent Document 2: Japanese Patent Laid-Open No. 2005-254974

DISCLOSURE OF THE INVENTION

In the cooling system of this prior art structure, the operations of a blower fan and the damper for blowing the air to the battery to cool down the battery cause unusual noise, such as wind roar. In general, the driver or the other passengers are not specifically informed of the operations of these components to cool down the battery. The occurrence of unusual noise in the course of cooling down the battery thus makes the driver and the other passengers feel odd and uncomfortable.

In the cooling system and the control method of the cooling system, there would thus be a demand for preventing the driver and the other passengers from feeling odd and uncomfortable by the occurrence of unusual noise in the course of cooling down a battery or an accumulator.

The present invention accomplishes at least part of the demand mentioned above and the other relevant demands by the following configurations applied to the cooling system and the control method of the cooling system.

According to one aspect, the present invention is directed to a cooling system constructed to cool down an accumulator mounted on a motor vehicle. The cooling system includes: an air blower provided to have multiple air blow modes of taking in the air from different locations and blowing the intake air to the accumulator; an air blow mode switchover module configured to change over a status of each air flow path between an open position and a closed position in each of the multiple air blow modes and thereby switch over an active air blow mode between the multiple air blow modes; and a controller configured to perform an air blow restriction changeover control, in response to a switchover demand of the active air blow mode during air blow to the accumulator via the air blow mode switchover module. The air blow restriction changeover control sequentially controls the air blower to restrict the air blow to the accumulator, controls the air blow mode switchover module to switch over the active air blow mode after restriction of the air blow to the accumulator, and controls the air blower to release the restriction of the air blow to the accumulator after the switchover of the active air blow mode by the air blow mode switchover module.

The cooling system according to this aspect of the invention has the air blow mode switchover module arranged to change over the status of each air flow path between the open position and the closed position in each of the multiple air blow modes of taking in the air from different locations and blowing the intake air to the accumulator. In response to a switchover demand of the active air blow mode during the air blow to the accumulator via the air blow mode switchover module, the cooling system of the invention performs the air blow restriction change over control. The air blow restriction changeover control sequentially controls the air blower to restrict the air blow to the accumulator, controls the air blow mode switchover module to switch over the active air blow mode after restriction of the air blow to the accumulator, and controls the air blower to release the restriction of the air blow to the accumulator after the switchover of the active air blow mode by the air blow mode switchover module. This arrangement reduces the potential unusual noise, such as wind roar, occurring in the course of a switchover of the air blow mode by the air blow mode switchover module and thus effectively prevents the driver and the other passengers from feeling odd and uncomfortable.

In one preferable embodiment, the cooling system of the above aspect further has: a noise level detection-estimation module configured to detect or estimate a noise level in a passenger compartment of the motor vehicle. The controller performs the air blow restriction changeover control in response to the detected or estimated noise level of less than a preset reference level, while controlling the air blow mode switchover module to switch over the active air blow mode without restriction of the air blow to the accumulator in response to the detected or estimated noise level of not less than the preset reference level. This arrangement desirably prevents the driver and the other passengers from feeling odd and uncomfortable by utilizing masking effects of the noise in the passenger compartment on unusual noise, such as wind roar, occurring due to the operations of the air blow mode switchover module. In this preferable embodiment, the noise level detection-estimation module may have a vehicle speed detector configured to detect a vehicle speed of the motor vehicle, and the noise level detection-estimation module may detect or estimate the noise level in the passenger compartment, based on the detected vehicle speed. In this preferable embodiment, when the cooling system is mounted on a motor vehicle equipped with an internal combustion engine, the noise level detection-estimation module may have an engine rotation speed detector configured to detect a rotation speed of the internal combustion engine, and the noise level detection-estimation module may detect or estimate the noise level in the passenger compartment, based on the detected rotation speed of the internal combustion engine. In this preferable embodiment, furthermore, when the cooling system is mounted on a motor vehicle equipped with an audio output module configured to output sound with an adjustable volume in the passenger compartment, the noise level detection-estimation module may detect or estimate the noise level in the passenger compartment, based on a volume adjustment condition of the audio output module.

In the cooling system according to the above aspect of the invention, the motor vehicle may be equipped with an air conditioner configured to condition the air in a passenger compartment of the motor vehicle, and the multiple air blow modes may include a first air blow mode of taking in the air inside or outside of the passenger compartment of the motor vehicle and directly blowing the intake air to the accumulator and a second air blow mode of taking in the air cooled down by the air conditioner and blowing the cooled intake air to the accumulator.

In the cooling system according to the above aspect of the invention, the cooling system may further include a temperature-relevant parameter detector configured to detect a temperature-relevant parameter reflecting temperature of the accumulator, and the switchover demand of the active air blow mode may be made based on the detected temperature-relevant parameter.

According to another aspect, the present invention is directed to a control method of a cooling system, the cooling system having: an air blower provided to have multiple air blow modes of taking in the air from different locations and blowing the intake air to an accumulator mounted on a motor vehicle; and an air blow mode switchover module configured to change over a status of each air flow path between an open position and a closed position in each of the multiple air blow modes and thereby switch over an active air blow mode between the multiple air blow modes, in response to a switchover demand of the active air blow mode during air blow to the accumulator via the air blow mode switchover module, the control method sequentially controlling the air blower to restrict the air blow to the accumulator, controlling the air blow mode switchover module to switch over the active air blow mode after restriction of the air blow to the accumulator, and controlling the air blower to release the restriction of the air blow to the accumulator after the switchover of the active air blow mode by the air blow mode switchover module.

The control method according to this aspect of the invention controls the cooling system having the air blow mode switchover module arranged to change over the status of each air flow path between the open position and the closed position in each of the multiple air blow modes of taking in the air from different locations and blowing the intake air to the accumulator. In response to a switchover demand of the active air blow mode during the air blow to the accumulator via the air blow mode switchover module, the control method of the invention performs the air blow restriction changeover control. The air blow restriction changeover control sequentially controls the air blower to restrict the air blow to the accumulator, controls the air blow mode switchover module to switch over the active air blow mode after restriction of the air blow to the accumulator, and controls the air blower to release the restriction of the air blow to the accumulator after the switchover of the active air blow mode by the air blow mode switchover module. This arrangement reduces the potential unusual noise, such as wind roar, occurring in the course of a switchover of the air blow mode by the air blow mode switchover module and thus effectively prevents the driver and the other passengers from feeling odd and uncomfortable.

In the control method according to this aspect of the invention, the control method may perform the air blow restriction changeover control in response to a noise level in a passenger compartment of the motor vehicle of less than a preset reference level, while controlling the air blow mode switchover module to switch over the active air blow mode without restriction of the air blow to the accumulator in response to the noise level in the passenger compartment of not less than the preset reference level. This arrangement desirably prevents the driver and the other passengers from feeling odd and uncomfortable by utilizing masking effects of the noise in the passenger compartment on unusual noise, such as wind roar, occurring due to the operations of the air blow mode switchover module. In the control method according to this aspect of the invention, the control method may perform the control in a motor vehicle equipped with an internal combustion engine, and may determine the noise level in the passenger compartment based on a rotation speed of the internal combustion engine and controls the air blow mode switchover module to switch over the active air blow mode. Furthermore, in the control method according to this aspect of the invention, the control method may perform the control in a motor vehicle equipped with an audio output device configured to output sound with an adjustable volume in the passenger compartment, and determine the noise level in the passenger compartment based on a volume adjustment condition of the audio output device and controls the air blow mode switchover module to switch over the active air blow mode.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically illustrates the configuration of a hybrid vehicle **20** in one embodiment of the invention;

FIG. **2** shows the schematic structure of a cooling system **60** for a battery **46**;

FIG. **3** is a flowchart showing a battery cooling routine executed by the hybrid electronic control unit **70**;

FIG. **4** shows one example of the cooling mode requirement setting map;

FIG. **5** is one example of a setting map of a target battery air volume Qb* in an inside air intake mode against a vehicle speed V;

FIG. **6** is one example of a setting map of a A/C air volume Qac and the target battery air volume Qb*in an A/C intake mode against the vehicle speed V;

FIG. **7** is a flowchart showing the mode switchover process;

FIG. **8** shows time changes of the air volume of a battery blower fan **64**, the air volume of an air-conditioning blower fan **55**, and the position of a mode switchover damper **68** in the case of a switchover of the cooling mode from the inside air intake mode to the A/C intake mode at the vehicle speed V of lower than a preset reference speed Vref; and

FIG. **9** shows time changes of the air volume of the battery blower fan **64**, the air volume of the air-conditioning blower fan **55**, and the position of the mode switchover damper **68** in the case of a switchover of the cooling mode from the A/C intake mode to the inside air intake mode at the vehicle speed V of lower than the preset reference speed Vref.

BEST MODES OF CARRYING OUT THE INVENTION

One mode of carrying out the invention is described below as a preferred embodiment with reference to the accompanied drawings. FIG. **1** schematically illustrates the configuration of a hybrid vehicle **20** in one embodiment of the invention. FIG. **2** shows the schematic structure of a cooling system **60** for a battery **46** in the embodiment. As illustrated in FIG. **1**, the hybrid vehicle **20** of the embodiment has an engine **22**, a planetary gear mechanism **28** having a carrier connected to a crankshaft **26** of the engine **22** and a ring gear connected to a driveshaft **34** that is linked with drive wheels **32***a* and **32***b* via a differential gear **31**, a motor MG**1** connected with a sun gear of the planetary gear mechanism **28** and designed to have power generation capability, a motor MG**2** designed to input and output power from and to a driveshaft **34**, the battery **46** arranged to transmit electric power to and from the motors MG**1** and MG**2** via inverters **42** and **44**, an air conditioner **50** configured to condition the air in a passenger compartment **90**, the cooling system **60** configured to use the air cooled down by the air conditioner **50** and thereby cool down the battery **46**, audio equipment **89** incorporated in a console panel in front of the driver's seat in the passenger compartment **90** and constructed to have a tuner (not shown), a speaker **89***a* for audio output, and a volume control button **89***b*, and a hybrid electronic control unit **70** configured to control the driving system of the vehicle and the cooling system **60** of the embodiment.

The engine **22** is under operation control of an engine electronic control unit (hereafter referred to as engine ECU) **24**. The operation control includes, for example, fuel injection control, ignition control, and intake air flow regulation. The engine ECU **24** inputs signals from various sensors designed to measure and detect the operating conditions of the engine **22**, for example, a crank position from a crank position sensor **23** attached to the crankshaft **26** of the engine **22**. The engine ECU **24** establishes communication with the hybrid electronic control unit **70** to drive and control the engine **22** in response to control signals received from the hybrid electronic control unit **70** and to output data regarding the operating conditions of the engine **22** to the hybrid electronic control unit **70** according to the requirements.

Both the motors MG**1** and MG**2** are driven and controlled by a motor electronic control unit (hereafter referred to as motor ECU) **48**. The motor ECU **48** inputs various signals required for driving and controlling the motors MG**1** and MG**2**, for example, signals representing rotational positions of rotors in the motors MG**1** and MG**2** from rotational position detection sensors (not shown) and signals representing phase currents to be applied to the motors MG**1** and MG**2** from current sensors (not shown). The motor ECU **48** outputs switching control signals to the inverters **42** and **44**. The motor ECU **48** establishes communication with the hybrid electronic control unit **70** to drive and control the motors MG**1** and MG**2** in response to control signals received from the hybrid electronic control unit **70** and to output data regarding the operating conditions of the motors MG**1** and MG**2** to the hybrid electronic control unit **70** according to the requirements.

As shown in FIGS. **1** and **2**, the air conditioner **50** has a compressor **51** configured to compress a coolant to high-temperature, high-pressure gas, a condenser **52** configured to cool down the compressed coolant with the outside air to high-pressure liquid, an expansion valve **53** configured to abruptly expand the cooled coolant to low-temperature, low-pressure mist, an evaporator **54** configured to evaporate the coolant to low-temperature, low-pressure gas by heat exchange between the low-temperature, low-pressure coolant and the air, and an air-conditioning blower fan **55** configured to blow the air cooled down by the heat exchange of the evaporator **54** to the passenger compartment **90**. The air-conditioning blower fan **55** is driven to take in the air from an inside air-outside air switchover damper **56** via a filter **57** and to cool down the intake air by the evaporator **54** and blow the cooled intake air to the passenger compartment **90**.

The air conditioner **50** is under control of an air-conditioning electronic control unit (hereafter referred to as air-conditioning ECU) **59**. The air-conditioning ECU **59** inputs an inside temperature Tin or temperature in the passenger compartment **90** from a temperature sensor **92**. The air-conditioning ECU **59** outputs driving signals to the compressor **51**, to the air-conditioning blower fan **55**, to the inside air-outside air switchover damper **56**, and to a mode switchover damper **68** (explained below). The air-conditioning ECU **59** establishes communication with the hybrid electronic control unit **70** to drive and control air conditioner **50** in response to control signals received from the hybrid electronic control unit **70** and to output data regarding the operating conditions of the air conditioner **50** to the hybrid electronic control unit **70**.

The cooling system **60** is arranged to take in the air from the passenger compartment **90** and directly blow the intake air to the battery **46**, so as to cool down the battery **46** (hereafter this cooling mode is referred to as inside air intake mode). The cooling system **60** is also arranged to alternately take in the air cooled down by the evaporator **54** of the air conditioner **50** and blow the cooled intake air to the battery **46**, so as to cool down the battery **46** (hereafter this cooling mode is referred to as A/C intake mode). As shown in FIG. **2**, the cooling system **60** has an air conduit **62** arranged to connect the passenger compartment **90** (inside air) with the battery **46**, a battery blower fan **64** provided on the air conduit **62** to blow the intake air to the battery **46**, a branch pipe **66** arranged to blow part of the air flowed from the air-conditioning blower fan **55** through the evaporator **54** to the upstream of the battery blower fan **64** in the air conduit **62**, and the mode switchover damper **68** provided at a joint of the air conduit **62** and the branch pipe **66** to selectively block the inside air or block the branch pipe **66**.

The hybrid electronic control unit **70** is constructed as a microcomputer including a CPU **72**, a ROM **74** configured to store processing programs, a RAM **76** configured to temporarily store data, input and output ports (not shown), and a communication port (not shown). The hybrid electronic control unit **70** inputs, via its input port, a battery temperature Tb or temperature of the battery **46** from a temperature sensor **47***a*, a charge-discharge electric current Ib from a current sensor **47***b* attached to an output terminal of the battery **46**, an intake air temperature Tbi from a temperature sensor **69** provided in the vicinity of an entrance to the battery **46** in the air conduit **62**, an ignition signal from an ignition switch **80**, a gearshift position SP or a current setting position of a gearshift lever **81** from a gearshift position sensor **82**, an accelerator opening Acc or the driver's depression amount of the accelerator pedal **83** from an accelerator pedal position sensor **84**, a brake pedal position BP or the driver's depression amount of the brake pedal **85** from a brake pedal position sensor **86**, a vehicle speed V from a vehicle speed sensor **88**, and an operation signal from the volume control button **89***b*. The hybrid electronic control unit **70** outputs driving signals to the battery blower fan **64** and to the other relevant elements via its output port. The hybrid electronic control unit **70** makes connection with the engine ECU **24**, the motor ECU **48**, and the air-conditioning ECU **59** via its communication port to transmit various control signals and data to and from the engine ECU **24**, the motor ECU **48**, and the air-conditioning ECU **59** as mentioned previously.

The following describes the operations of the hybrid vehicle **20** of the embodiment having the configuration discussed above, especially a series of operations to cool down the battery **46**. FIG. **3** is a flowchart showing a battery cooling routine executed by the hybrid electronic control unit **70**. This routine is repeatedly performed at preset time intervals (for example, at every several ten msec) when the battery temperature Tb measured by the temperature sensor **47***a* is not lower than a preset reference temperature (for example, 50° C.).

In the battery cooling routine, the CPU **72** of the hybrid electronic control unit **70** first inputs various data required for control, for example, the intake air temperature Tbi from the temperature sensor **69**, a battery load Lb of the battery **46**, the vehicle speed V from the vehicle speed sensor **88**, and an A/C air volume Qac of the air conditioner **50** (step S**100**). The battery load Lb of the battery **46** may be obtained by averaging a preset number of computed values of charge-discharge electric power of the battery **46** (the product of the square of the charge-discharge electric current Ib measured by the current sensor **47***b* and an internal resistance of the battery **46**). The A/C air volume Qac of the air conditioner **50** is set based on the user's set air volume as the air flow to be blown out to the passenger compartment **90**, the user's set temperature, and the inside temperature Tin from the temperature sensor **92** and is input from the air-conditioning ECU **59** by communication.

After the data input, the CPU **72** identifies a required setting of a cooling mode Mc, based on the input intake air temperature Tbi and the input battery load Lb (step S**110**). The required setting of the cooling mode Mc is identified according to the intake air temperature Thi and the battery load Lb with referring to a cooling mode requirement setting map. One example of the cooling mode requirement setting map is shown in FIG. **4**. The intake air temperature Thi and the battery load Lb are parameters significantly affecting the temperature of the battery **46** (battery temperature Tb). The higher intake air temperature Tbi and the greater battery load Lb lead to a significant increase in temperature of the battery **46** and thereby require accelerated cooling of the battery **46**. In this case, the required setting of the cooling mode Mc is the A/C intake mode. The lower intake air temperature Thi and the smaller battery load Lb, on the other hand, lead to a relatively small increase in temperature of the battery **46** and thereby do not require accelerated cooling of the battery **46**. In this case, the required setting of the cooling mode Mc is the inside air intake mode. When the required setting of the cooling mode Mc is different from the current setting of the cooling mode Mc, there is a requirement for switching over the cooling mode Mc.

When the required setting of the cooling mode Mc is the inside air intake mode (step S**120**), the CPU **72** sets a target battery air volume Qb* to be blown to the battery **46** based on the input vehicle speed V (step S**130**) and controls the operation of the battery blower fan **64** with the set target battery air volume Qb* (step S**180**). The battery cooling routine is then terminated. A concrete procedure of setting the target battery air volume Qb* in the inside air intake mode in this embodiment provides and stores in advance a variation in target battery air volume Qb* against the vehicle speed V as a map in the ROM **74** and reads the target battery air volume Qb* corresponding to the given vehicle speed V from the stored map. One example of this map is shown in FIG. **5**. The higher vehicle speed V leads to the larger drive-related noise and gives the greater background noise to the driver and the other passengers. In general, the driver or the other passengers are not specifically informed of the operation of the battery blower fan **64**. The operation of the battery blower fan **64** at a high rotation speed may thus cause the driver and the other passengers to feel odd and uncomfortable by the unexpected large driving noise. In order to effectively mask the driving noise of the battery blower fan **64** with the background noise increasing with an increase in vehicle speed V, the operation of the battery blower fan **64** is allowed to have the greater target battery air volume Qb* in the condition of the higher vehicle speed V. The battery blower fan **64** is thus driven to cool down the battery **46** in a specific range of not making the driver or the other passengers feel odd or uncomfortable.

When the required setting of the cooling mode Mc is the A/C intake mode (step S**120**), on the other hand, the CPU **72** sets the target battery air volume Qb* based on the input vehicle speed V and the input A/C air volume Qac (step S**140**) and gives an air volume increase instruction to the air-conditioning ECU **59** to increase the A/C air volume Qac by the set target battery air volume Qb* (step S**150**). The CPU **72** then controls the operation of the battery blower fan **64** with the set target battery air volume Qb* (step S**180**) and terminates the battery cooling routine. In response to this air volume increase instruction, the air-conditioning ECU **59** operates the air-conditioning blower fan **55** with the A/C air volume Qac increased by the target battery air volume Qb*. The air blow to the battery **46** with the intake air blown by the air-conditioning blower fan **55** operated to have the increased A/C air volume Qac by the target battery air volume Qb* accordingly does not affect the air conditioning in the passenger compartment **90**. A concrete procedure of setting the target battery air volume Qb*in the A/C intake mode in the embodiment provides and stores in advance variations in target battery air volume Qb* against the vehicle speed V with regard to multiple values of the A/C air volume Qac as a map in the ROM **74** and reads the target battery air volume Qb* corresponding to the given vehicle speed V and the given A/C air volume Qac from the stored map. One example of this map is shown in FIG. **6**. As shown in this map, the target battery air volume Qb* in the A/C intake mode is set to be smaller than the target battery air volume Qb* in the inside air intake mode at an identical value of the vehicle speed V, because of the following reason. In the A/C intake mode, the air-conditioning blower fan **55** for the air conditioner **50** is driven with the A/C air volume Qac increased by the target battery air volume Qb*. The driving noise of the air-conditioning blower fan **55** is thus greater than the driving noise of the battery blower fan **64** in the A/C intake mode. This increases the potential of making the driver and the other passengers feel odd and uncomfortable.

In response to a switchover requirement for switching over the cooling mode Mc at step S**120**, when a switchover of the cooling mode Mc is not currently being done (step S**160**), the CPU **72** starts a mode switchover process (step S**170**). The CPU **72** then controls the operation of the battery blower fan **64** (step S**180**) and terminates the battery cooling routine. FIG. **7** is a flowchart showing the mode switchover process executed in parallel to the battery cooling routine by the hybrid electronic control unit **70** in the embodiment. The details of the mode switchover process are explained below.

In the mode switchover process, the CPU **72** of the hybrid electronic control unit **70** first inputs the vehicle speed V (step S**200**) and compares the input vehicle speed V with a preset reference speed Vref (step S**210**). The reference speed Vref is experimentally set as a vehicle speed criterion of sufficiently masking the potential wind roar in the course of a changeover of the position of the mode switchover damper **68** with the drive-related noise. When the vehicle speed V is not lower than the preset reference speed Vref, the CPU **72** gives an instruction to the air-conditioning ECU **59** to immediately change over the position of the mode switchover damper **68** (step S**240**). The CPU **72** waits for completion of the position changeover of the mode switchover damper **68** (step S**250**) and sets a changeover completion flag F to 1 (step S**260**). The mode switchover process is then terminated. The higher vehicle speed V leads to the larger drive-related noise (the greater background noise). The wind roar or unusual noise potentially occurring in the course of the position changeover of the mode switchover damper **68** is thus effectively masked with the background noise and desirably prevents the driver and the other passengers from feeling odd and uncomfortable. One procedure of identifying completion of the position changeover of the mode switchover damper **68** determines whether a predetermined time period slightly longer than a required time generally required for the position changeover of the mode switchover damper **68** has been elapsed. Another procedure uses a sensor for detecting the position of the mode switchover damper **68** and identifies completion of the position changeover of the mode switchover damper **68** based on a signal output from the sensor. In response to the setting of the changeover completion flag F to 1, it is identified that the switchover of the cooling mode Mc is completed. Until a next switchover requirement for switching over the cooling mode Mc at step S**120**, in response to the switchover of the cooling mode Mc to the inside air intake mode, the battery cooling routine of FIG. **3** goes to the processing flow of and after step S**130**. In response to the switchover of the cooling mode Mc to the A/C intake mode, the battery cooling routine of FIG. **3** goes to the processing flow of and after step S**140**.

When the vehicle speed V is lower than the preset reference speed Vref, on the other hand, the CPU **72** restricts the target battery air volume Qb* of the battery blower fan **64** to a preset limit level Qlim (step S**220**). The CPU **72** waits for elapse of a predetermined time period required for lowering the actual air volume of the air blow to the battery **46** to the preset limit level Qlim (step S**230**) and gives an instruction to the air-conditioning ECU **59** to change over the position of the mode switchover damper **68** (step S**240**). The CPU **72** waits for completion of the position changeover of the mode switchover damper **68** (step S**250**) and sets the changeover completion flag F to 1 (step S**260**). The mode switchover process is then terminated. The limit level Qlim is experimentally set as an air volume criterion for reducing the potential wind roar occurring in the course of a position changeover of the mode switchover damper **68** to a specific range of presenting the driver and the other passengers from feeling odd and uncomfortable. When the drive-related noise (background noise) is too small to sufficiently mask the wind roar occurring in the course of the position changeover of the mode switchover damper **68**, the target battery air volume Qb* of the battery blower fan **64** is restricted to reduce the potential wind roar occurring in the course of the position changeover of the mode switchover damper **68** and thereby prevents the driver and the other passengers from feeling odd and uncomfortable.

FIG. **8** shows time changes of the air volume of the battery blower fan **64**, the air volume of the air-conditioning blower fan **55**, and the position of the mode switchover damper **68** in the case of a switchover of the cooling mode from the inside air intake mode to the A/C intake mode at the vehicle speed V of lower than the preset reference speed Vref. FIG. **9** shows time changes of the air volume of the battery blower fan **64**, the air volume of the air-conditioning blower fan **55**, and the position of the mode switchover damper **68** in the case of a switchover of the cooling mode from the A/C intake mode to the inside air intake mode at the vehicle speed V of lower than the preset reference speed Vref. In the time chart of FIG. **8**, in response to a switchover requirement of the cooling mode from the inside air intake mode to the A/C intake mode at a time t**1**, the target battery air volume Qb* of the battery blower fan **64** is restricted to the preset limit level Qlim. At a time t**2**, a changeover operation starts to change over the position of the mode switchover damper **68** to the A/C intake mode. On completion of the position changeover of the mode switchover damper **68** at a time t**3**, the air blow to the battery **46** in the A/C intake mode starts with release of the restriction of the target battery air volume Qb*. In the time chart of FIG. **9**, in response to a switchover requirement of the cooling mode from the A/C intake mode to the inside air intake mode at a time t**4**, the target battery air volume Qb* of the battery blower fan **64** is restricted to the preset limit level Qlim, while the increase of the A/C air volume Qac by the target battery air volume Qb* is cancelled. At a time t**5**, a changeover operation starts to change over the position of the mode switchover damper **68** to the inside air intake mode. On completion of the position changeover of the mode switchover damper **68** at a time t**6**, the air blow to the battery **46** in the inside air intake mode starts with release of the restriction of the target battery air volume Qb*.

As described above, the hybrid vehicle **20** of the embodiment switches over the cooling mode Mc between the inside air intake mode and the A/C intake mode by changing over the position of the mode switchover damper **68**. The position changeover of the mode switchover damper **68** selectively disconnects either the air conduit **62** in the inside air intake mode of taking in the air in the passenger compartment **90** and directly blowing the intake air to the battery **46** or the branch pipe **66** in the A/C intake mode of taking in the air cooled down by the air conditioner **50** and blowing the cooled intake air to the battery **46**. In response to a switchover requirement of the cooling mode Mc, the air volume of the battery blower fan **64** (target battery air volume Qb*) is restricted to the preset limit level Qlim, prior to the changeover of the position of the mode switchover damper **68**. Such control reduces the potential wind roar occurring in the course of a position changeover of the mode switchover damper **68** and thus effectively prevents the driver and the other passengers from feeling odd and uncomfortable. At the vehicle speed V of not lower than the preset reference speed Vref, the position changeover of the mode switchover damper **68** is controlled to immediately switch over the cooling mode Mc. Such control sufficiently masks the unusual noise, such as the wind roar, potentially occurring in the course of a position changeover of the mode switchover damper **68** with the drive-related noise and thus effectively prevents the driver and the other passengers from feeling odd and uncomfortable.

When the vehicle speed V is lower than the preset reference speed Vref, in response to a switchover requirement of the cooling mode Mc, the hybrid vehicle **20** of the embodiment restricts the target battery air volume Qb* of the battery blower fan **64** to the preset limit level Qlim, prior to the changeover of the position of the mode switchover damper **68**. When the vehicle speed V is not lower than the preset reference speed Vref, on the other hand, in response to a switchover requirement of the cooling mode Mc, the hybrid vehicle **20** of the embodiment immediately changes over the position of the mode switchover damper **68**. Such conditional restriction of the target battery air volume Qb* is, however, not restrictive. One modification may unconditionally restrict the target battery air volume Qb* of the battery blower fan **64** to the preset limit level Qlim, independently of the vehicle speed V, prior to the changeover of the position of the mode switchover damper **68**.

The hybrid vehicle **20** of the embodiment uses the vehicle speed V as a parameter reflecting the noise in the passenger compartment **90** (background noise) or a noise estimation parameter. The vehicle speed V may be replaced by any other suitable parameter reflecting the noise in the passenger compartment **90** (background noise). Available examples of the parameter reflecting the noise in the passenger compartment **90** (background noise) include a rotation speed Ne of the engine **22** computed from a signal representing the crank position detected by the crank position sensor **23**, a volume level adjusted by the volume control button **89***b* of the audio equipment **89**, and a noise level actually detected by a microphone located in the passenger compartment **90**.

The hybrid vehicle **20** of the embodiment identifies the required setting of the cooling mode Mc, based on the intake air temperature Tbi and the battery load Lb. The required setting of the cooling mode Mc may be identified based on only the intake air temperature Tbi, based on only the battery load Lb, or based on another suitable parameter, for example, the battery temperature Tb or its increase rate.

In the hybrid vehicle **20** of the embodiment, the cooling system **60** has the inside air intake mode of taking in the air in the passenger compartment **90** and directly blowing the intake air to the battery **46** and the A/C intake mode of taking in the air cooled down by the air conditioner **50** (evaporator **54**) and blowing the cooled intake air to the battery **46**, as the available options of the cooling mode Mc. The available options of the cooling mode Mc are, however, not restricted to these modes. The technique of the invention is applicable to any cooling system having at least two different modes of taking in the air from different locations and blowing the intake air to the battery. The available options of the cooling mode Mc may include an outside air intake mode of taking in the outside air and blowing the intake air to the battery or a trunk room air intake mode of taking in the air in a vehicle trunk room and blowing the intake air to the battery.

The embodiment regards the cooling system **60** as one application of the invention to cool down the battery **46**, which is arranged to transmit electric power to and from the motors MG**1** and MG**2** in the hybrid vehicle **20** equipped with the engine **22**, the planetary gear mechanism **28**, and the motors MG**1** and MG**2**. This is, however, not restrictive in any sense. The cooling system of the invention may be applied to cool down a battery or another accumulator arranged to transmit electric power to and from a driving motor in a hybrid vehicle of another configuration or may be applied to cool down a battery or another accumulator arranged to transmit electric power to and from a motor in an electric vehicle equipped with only the motor as the driving power source. The cooling system of the invention may also be applied to cool down an accumulator used for an auto start in a motor vehicle having engine auto stop and auto start functions.

The embodiment and its modified examples discussed above are to be considered in all aspects as illustrative and not restrictive. There may be many other modifications, changes, and alterations without departing from the scope or spirit of the main characteristics of the present invention.

Industrial Applicability

The technique of the present invention is preferably applied to the manufacturing industries of the cooling systems and the motor vehicles.

The invention claimed is:

1. A cooling system for cooling down an accumulator mounted on a motor vehicle, the cooling system comprising:

an air blower configured to have multiple air blow modes of taking in an intake air from different air flow paths within the cooling system and blowing the intake air to the accumulator;

an air blow mode switchover module configured to changeover a status of each air flow path within the cooling system between an open position and a closed position in each of the multiple air blow modes to thereby switch over to an active air blow mode from among the multiple air blow modes;

a noise level detection-estimation module configured to detect or estimate a noise level in a passenger compartment of the motor vehicle; and

a controller configured, in response to a switch over demand of the active air blow mode during air blow to the accumulator, to perform an air blow restriction changeover control in a case that the detected or estimated noise level is less than a preset reference level, while controlling the air blow mode switchover module to switch over to the active air blow mode without restriction of the air blow to the accumulator in a case that the detected or estimated noise level is not less than the preset reference level, wherein

the air blow restriction changeover control sequentially controls: i) the air blower to restrict the air blow to the accumulator, ii) the air blow mode switchover module to switch over to the active air blow mode after restriction of the air blow to the accumulator, and iii) the air blower to release the restriction of the air blow to the accumulator after the switch over to the active air blow mode by the air blow mode switchover module, and

when a detected speed of the motor vehicle is not lower than a reference speed, a position of a damper is immediately changed over, and

when a detected speed of the motor vehicle is lower than the reference speed, the air blower speed is restricted to a preset level, prior to changing over the position of the damper.

2. The cooling system in accordance with claim **1**, wherein

the cooling system is mounted on a motor vehicle equipped with an internal combustion engine,

the noise level detection-estimation module has an engine rotation speed detector configured to detect a rotation speed of the internal combustion engine, and

the noise level detection-estimation module detects or estimates the noise level in the passenger compartment, based on the detected rotation speed of the internal combustion engine.

3. The cooling system in accordance with claim **1**, wherein

the cooling system is mounted on a motor vehicle equipped with an audio output module configured to output sound with an adjustable volume in the passenger compartment, and

the noise level detection-estimation module detects or estimates the noise level in the passenger compartment, based on a volume adjustment condition of the audio output module.

4. The cooling system in accordance with claim **1**, wherein

the motor vehicle is equipped with an air conditioner configured to condition air in the passenger compartment of the motor vehicle, and

the multiple air blow modes include a first air blow mode of taking in the air inside or outside of the passenger compartment of the motor vehicle and directly blowing the intake air to the accumulator and a second air blow mode of taking in the air cooled down by the air conditioner and blowing the cooled intake air to the accumulator.

5. The cooling system in accordance with claim **1**, further comprising:

a temperature-relevant parameter detector configured to detect a temperature-relevant parameter reflecting a temperature of the accumulator, wherein

the switch over demand of the active air blow mode is made based on the detected temperature-relevant parameter.

6. A method for controlling a cooling system, the cooling system including an air blower provided to have multiple air blow modes of taking in an intake air from different air flow paths within the cooling system and blowing the intake air to an accumulator mounted on a motor vehicle; and an air blow mode switchover module configured to changeover a status of each air flow path within the cooling system between an open position and a closed position in each of the multiple air blow modes to thereby switch over to an active air blow mode from among the multiple air blow modes, the method comprising:

in response to a switch over demand of the active air blow mode during air blow to the accumulator, the method performs an air blow restriction changeover control in a case that a noise level in a passenger compartment of the motor vehicle is less than a preset reference level, while controlling the air blow mode switchover module to switch over to the active air blow mode without restriction of the air blow to the accumulator in a case that the noise level in the passenger compartment is not less than the preset reference level, wherein

the air blow restriction changeover control sequentially controls: i) the air blower to restrict the air blow to the accumulator, ii) the air blow mode switchover module to switch over to the active air blow mode after restriction of the air blow to the accumulator, and iii) the air blower to release the restriction of the air blow to the accumulator after the switch over of the active air blow mode by the air blow mode switchover module,

when a detected speed of the motor vehicle is not lower than a reference speed, a position of a damper is immediately changed over, and

when a detected speed of the motor vehicle is lower than the reference speed, the air blower speed is restricted to a preset level, prior to changing over the position of the damper.

7. The method in accordance with claim **6**, wherein

the method performs the controlling in a motor vehicle equipped with an internal combustion engine, and

the control method determines the noise level in the passenger compartment based on a rotation speed of the internal combustion engine and controls the air blow mode switchover module to switch over to the active air blow mode.

8. The method in accordance with claim **6**, wherein

the method performs the controlling in a motor vehicle equipped with an audio output device configured to output sound with an adjustable volume in the passenger compartment, and

the method determines the noise level in the passenger compartment based on a volume adjustment condition of the audio output device and controls the air blow mode switchover module to switch over to the active air blow mode.

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